

Global Land Ice Measurements from Space
NASA award number NAG5-9722

Final Report
31 July 2004

PI: Gregory R. Scharfen
Co-PI: Vincent J. Troisi
Co-PI: Roger G. Barry

National Snow and Ice Data Center (NSIDC)
University of Colorado

Reporting period: 1 July 2000 – 31 July 2004

Background:

The NSIDC at the University of Colorado has successfully completed the tasks outlined in its proposal 0999.08.1216B, the "Global Land Ice Measurements from Space" grant funded by NASA under NAG5-9722.

The Global Land Ice Measurements from Space (GLIMS) grant reported on here is one of the first completed elements of the overall GLIMS project that continues with separate funding from NASA, the United States Geological Survey (USGS), and internationally by many national agencies and universities. The primary goals of GLIMS are to survey significant numbers of the world's 160,000 glaciers with data collected by the ASTER (Advanced Spaceborne Thermal Emission and reflection Radiometer) instrument aboard the EOS Terra spacecraft, and Landsat ETM+ (Enhanced Thematic Mapper Plus) and to make these data available to users in a common and easily usable format. GLIMS participants include: NSIDC as developer of the GLIMS database, USGS Flagstaff as the GLIMS Coordination Center, USGS EROS Data Center (EDC) as the archive for satellite imagery used in GLIMS analyses (NASA funding for GLIMS also includes the Flagstaff group and EDC through the related ASTER Science Team and Land Processes Distributed Active Archive Center [LP DAAC] activities), and approximately twenty two Regional Centers (RCs). RCs are funded by the national agencies of participating countries to analyze satellite imagery for a specified set of glaciological parameters and provide the results to NSIDC for archive and distribution to the public.

The international GLIMS effort is well underway. A network of RCs and their Stewards have responsibility for specified regions covering all glaciated areas of the world. RCs were selected based on their demonstrated expertise with particular glaciers, and their ability to deliver the scientific analyses which are the primary output of the GLIMS project. Agreements identifying expectations and responsibilities have been signed with

the RCs. Several tens of thousands of ASTER images suitable for GLIMS analyses have been acquired for glaciated regions of the world. These data are being made available by the LP DAAC. ASTER image collection will continue in accordance with an image collection schedule for GLIMS that has been established with the U.S. and Japanese ASTER Science Teams. NASA has also sponsored the purchase of suitable LANDSAT scenes that will be used in the analyses. A draft version of customized image analysis software for GLIMS (GLIMSVIEW) has been developed by NSIDC and the Flagstaff group.

The GLIMS grant we report on here is an integral part of the larger effort. Creation of the initial GLIMS information management system, as outlined in the proposal, and the various interfaces with the public and with our partners is complete, however we have since identified many aspects of GLIMS that will continue to evolve in the coming years. NSIDC at the University of Colorado will continue its involvement in the GLIMS effort beyond the end of the current grant with new funding (NSIDC submitted successful GLIMS-related proposals to both the NASA CAN-02-OES-1 and NASA NRA-03-OES-02 calls). Dr. Richard Armstrong is the PI on both of these new grants.

Highlights from NAG5-9722:

NSIDC has successfully completed the tasks that were identified in the proposal for this grant. This primarily involved the development of a database to contain the globally distributed glacier measurements provided by the RCs. This has resulted in a functioning information management system for GLIMS, one that will continue to evolve to meet the needs of GLIMS (see below). Selected highlights from this grant are listed in Table 1.

Table 1: Selected highlights and status

1. Data base implementation	Data base design, valids, ERD, data dictionary complete, populated with test data sets, and initial results from selected RCs
2. Transfer format	Complete, data transfer specification published on web
3. Coordinate system	Complete, longitude/latitude on the WGS84 datum
4. User search interface	Pre-release version functional, web-server version under development with separate funding
5. Ingest processing module	Complete
6. Data submissions	Preliminary submissions beginning, mockup data sets for testing completed, testing underway
7. GLIMSVIEW Analysis Software	Windows and Linux versions available, users guides and tutorials published on web

The database design, data transfer specification, ingest module and pre-release user interface are complete. The database design reflects extensive input from the glaciological community, and includes over twenty tables. The two main tables are

called Glacier_Static and Glacier_Dynamic. Glacier_Static stores static (unchanging) information, such as glacier name, and Glacier_Dynamic stores the measured attributes of a glacier, including its outline, speed, snowline elevation, descriptive characteristics compatible with the World Glacier Inventory, as well as metadata such as name of analysts and their institutions, and pointers to source data.

Simple user interfaces for data submission and search and order have been created. The data submission interface includes a GLIMS data agreement between NSIDC and the RCs which defines the responsibilities of NSIDC in maintaining the GLIMS database and the RCs in submitting analyses to the GLIMS database. These interfaces have been tested by several of the RCs, although we expect to improve them with the follow-on funding. We have worked closely with several of the RCs to test the submission of data to the archive and its availability through the user interface.

Initial test results from RCs include measurements of glacier geometry, surface velocity, and snowline elevation. Recently, we worked closely with several RCs during working visits to NSIDC (funded through and NSF-sponsored workshop) to facilitate the analysis of imagery for GLIMS database attributes, and their ingest, archive and distribution using the system that we have developed to date. During these visits, NSIDC assisted RCs in using the GLIMSview software, then later we worked with the GLIMS group at Flagstaff to improve it based on the practical feedback we got from the RCs. The submission of several new GLIMS data sets from the RCs also resulted from this activity.

The system we are developing with the follow-on funding will provide these data in a standard format for archival and use by the research community via a map server on the World Wide Web.

A GLIMS analysis tutorial has been written by Bruce Raup as part of this grant. This document, designed to guide RCs through the analysis process, is available on the GLIMS website (<http://nsidc.org/data/glims/>).

To quantify and understand the variability in analyses by RCs, we are conducting a 'round robin' test in which RCs analyze a common set of imagery, using whatever tools they choose (including GLIMSview), to produce glacier outlines and other GLIMS attributes. This test will continue for several months with other GLIMS support. The results will be published.

Conclusions:

As contributions from the network of Regional Centers increase, and other relevant data sets are included, the GLIMS information management system will provide a valuable, easy to use and widely accessible service for the glaciological community, modelers and other users needing information about the world's glaciers. The GLIMS project, specifically the data base and enhanced interface to its contents will contribute to NASA's Earth Science Enterprise science goals by providing a unique record of high quality glacier observations, that are made available to scientists, policy makers and educators through an innovative and adaptable interface.

Publications:

Many publications have resulted from this activity; refereed articles and key abstracts are listed below:

Kargel, J., H. Kieffer, R. Barry, M. Bishop, D. MacKinnon, B. Raup, J. Shroder, G. Scharfen, V. Troisi, "Worldwide Glacier Observations Planned by ASTER", *Eos, Transactions, American Geophysical Union*, Vol. 81, No. 19, S143, May 9, 2000.

Kargel, J., H. Kieffer, R. Barry, M. Bishop, D. MacKinnon, K. Mullins, B. Raup, G. Scharfen, J. Shroder, R. Wessels, "Initial Glacier Images from ASTER and Test Analysis for GLIMS", *Eos, Transactions, American Geophysical Union*, Vol. 81, No. 48, F548, November 28, 2000.

Khalsa, S.J.S., M. Dyurgerov, T. Khromova, B. Raup and R. Barry. Space-Based Mapping of Glacier Changes using ASTER and GLIS Tools. International Geoscience and Remote Sensing Symposium 2003, Toulouse, France, 21-25 July 2003.

Khalsa, S.J., B. Raup, G.R. Scharfen, V.J. Troisi, R. Swick, I. Wang, A.E. Machado, R.G. Barry, "A Functional Demonstration of the GLIMS Information Management System" IGARSS 2002, June 2002, Toronto

Khromova, T., M. Dyurgerov, and R. Barry. 2003. Late-twentieth century changes in glacier extent in the Ak-shirak Range, central Asia, determined from historical and ASTER imagery. *Geophys. Res. Lett.* 30(16), 1863, HLS 2.1-2.5, doi.10.1029/2003GL017233

Kieffer, H., J. Kargel, R. Barry, G. Scharfen (and many others), "New Eyes in the Sky for Measurements of Glaciers and Ice Sheets", *Eos, Transactions American Geophysical Union*, Vol. 81, No. 4, p. 265, 270-1, January 18, 2000.

Raup, B.H., Keiffer, H.H., Hare, T.M., and Kargel, J.S., Generation of Data Acquisition Requests for the ASTER Satellite Instrument for Monitoring a Globally Distributed Target (PDF) - in *IEEE Transactions of Geoscience and Remote Sensing*, Vol. 38, No. 2, March 2000

Scharfen, G., R. Barry, V. Troisi, S. Khalsa, R. Weaver, B. Raup, "The Glacier Land Ice Measurements from Space (GLIMS) World Data Archive: An Information Management System for GLIMS", *Eos Transactions American Geophysical Union*, Vol. 80, No. 46, p. F329, November 16, 1999.

Troisi, V.T., G.R. Scharfen, B. Raup, S.J. Khalsa, R. Swick, I.P. Wang, R.G. Barry, M. Dyurgerov, T. Khromova, Readiness of the Global Land Ice Measurements from Space (GLIMS) Database at NSIDC, *Eos. Trans. AGU*, 83(47) Fall Meet. Suppl., 2002. p.F312.

Raup, B., H. Kieffer, T. Hare, J. Kargel, "Generation of Data Acquisition requests for the ASTER Satellite Instrument for Monitoring a Globally Distributed Target: Glaciers", IEEE Transactions on Geoscience and Remote Sensing, Vol. 38, No. 2, p.1105-1112, March 2000.